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THE EFFECTS OF STIMULUS ORIENTATION AND RESPONSE BIAS
UPON DYNAMIC VISUAL ACUITY

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⑥ The Effects of Stimulus Orientation and Response Bias
Upon Dynamic Visual Acuity .

⑩ LTJG Lawrence H. Frank, MSC, USNR

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⑭ NAMRL-1241

⑮ F51524

Naval Medical Research and Development Command

⑰ MF51 524 7004/2011

Naval Air Systems Command
W43-13 8881

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⑪ 19 August 1977

⑫ 19p.

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SUMMARY PAGE

THE PROBLEM

In experiments on dynamic visual acuity, test stimuli are characteristically presented in various orientations to the subject as they are moved across his visual field. However, current literature on static visual acuity indicates that acuity thresholds vary as a function of stimulus orientation. Static acuity thresholds are reported to be lower for the vertical and horizontal orientations, whereas, higher thresholds are found for oblique orientations. This has been referred to as the "oblique effect."

It is not known whether the same phenomenon operates in dynamic visual acuity. Hence, it is of interest to determine whether such an effect occurs under moving target conditions. The present studies utilized the up-and-down method to determine acuity thresholds for eight orientations (4 cardinal and 4 oblique) of Landolt Cs over three angular velocities. Response-bias scores were computed for each subject and compared to the threshold data.

FINDINGS

A significant orientation effect was found for both dynamically and statically presented targets, but it was not an oblique effect. That is, thresholds were not consistently higher for oblique orientations. The data further revealed a significant negative rank-order correlation between the subjects' response-bias scores and their threshold scores across orientations, for dynamically presented targets. The data were suggestive that a subject's response bias contributes to the error in the measurement of psychophysically derived acuity thresholds.

ACKNOWLEDGEMENTS

The author wishes to express his appreciation to T. R. Morrison, Dr. D. E. Egan, Dr. J. E. Goodson, and especially to Dr. D. J. Weintraub, for their time, ideas, and comments.

Opinions or conclusions contained in this report are those of the author and do not necessarily reflect the view or the endorsement of the Navy Department.

INTRODUCTION

A voluminous literature has accrued indicating that man detects and resolves stimuli better when they are oriented vertically or horizontally rather than obliquely. Appelle (1) has referred to this phenomenon as the "oblique effect." Studies of visual acuity have generally supported the oblique effect (2, 3, 5, 6, 7, 8, 9, 12, 13) by obtaining higher acuity thresholds for test stimuli presented in oblique orientations, rather than in cardinal orientations (horizontal and vertical).

Recently, Weitzman, Smith, and Karasik (13) have applied the technique of signal detection theory to the analysis of variations in acuity between vertical and horizontal gratings. Their findings indicated that orientation effects may not only be explained in terms of visual neurological mechanisms (e.g., 10), but also in terms of the decision-making processes of the observer. Weitzman's et. al. data indicate that a subject's decision criteria (which can lead to response bias) should be evaluated concurrently with psychophysically derived threshold measures.

Although the oblique effect has been well documented for static visual acuity (SVA), no systematic research pertaining to this effect has been conducted relative to a dynamic visual acuity (DVA) task. One would expect that if the oblique effect is a consequence of receptor and neural functioning, it would be demonstrable in a dynamic situation as well as a static one. The purposes of this study were to ascertain whether subjects tested on a DVA task exhibit the oblique effect, and to examine the role of the subject's response bias on the psychophysically derived acuity thresholds.

EXPERIMENT I

METHOD

SUBJECTS

Two males, DW and TM, served as subjects in the present experiment. Both subjects wore corrective lenses and were aware of the purposes of the study.

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STIMULI

The stimuli consisted of 12 Landolt-C rings varying in size from 0.65 to 9.31 minutes of arc at the subject's eye. The stimuli were photographs developed on non-gloss Kodak print paper having a 91 percent negative contrast as computed from measurements made by a Spectra Brightness Spot Meter (Model UB - 1/4⁰) manufactured by Photo-Research Corp. Contrast was defined as the ratio of the difference in luminance between the target and background to the background luminance, multiplied by 100.

APPARATUS

The apparatus consisted of a rotating mirror through which the subject viewed the stimulus. A front-surfaced mirror, 10.16 cm high and 25.4 cm long, was positioned such that its center of rotation was 590.12 cm from a stimulus background screen and 19.05 cm from the subject's eye. A variable-speed motor and pulley system enabled the experimenter to produce the desired mirror speed for stimulus presentation. Counterclockwise movement of the mirror resulted in the stimulus image moving from right to left across the mirror during a 0.4-sec. exposure period. Stimulus exposure time was held constant by placing a flat-white cardboard mask with a 2.54 cm high aperture over the mirror. The length of the rectangular aperture varied as a function of the target speed to ensure a constant exposure time for each velocity.

The curved background screen was 75.26⁰ in azimuth and constructed of seamless white paper. A 19.05 cm circular aperture was cut in the background screen 35.86⁰ from its right edge. This aperture was used for stimulus presentation with the experimenter standing behind the screen and out of view of the subject. When the stimulus was in position, it filled the aperture in the screen. When the subject's eye was correctly positioned in the apparatus, he could see in the mirror a uniform area of screen subtending 11.8⁰ of visual angle vertically.

Two COLORTAN luminaires equipped with 750 watt tungsten-halogen lamps, having a color temperature of 3200⁰K, provided an average luminance of 44 ft-L around the stimulus. The luminances of the other vertical surfaces in the room were made more nearly uniform by means of screens, flat-white paint, and auxiliary lighting.

PROCEDURES AND EXPERIMENTAL DESIGN

Both subjects were tested monocularly with their right eye. The left eye was occluded. The subject placed his head in a chin-and-headrest assembly that could be adjusted vertically, horizontally, and along the eye-to-mirror axis. When the subject's eye was in the proper position, the effective eye-to-target viewing distance was 608.60 cm. The angle formed between the line of

sight to the center of the mirror, and the line from the center of the mirror to the target, was 104.8° .

At the beginning of each session, the mirror was aligned and set to the correct speed setting. Target velocities were 20° and 110° /sec. The experimenter placed the stimulus in position prior to the mirror's surface coming into the subject's view and notified the subject by saying "ready." After target presentation, the subject made a forced-choice verbal response corresponding to one of the eight Landolt-C gap orientations. Stimulus gap size for each trial was determined by the up-and-down method. If the subject made a correct response, the gap size was reduced on subsequent trials until an incorrect response occurred. When an incorrect response occurred, the gap was increased in size until a correct response was made. This method of presentation continued until 54 trials following the first reversal in the series had occurred. Thus, the size of the stimulus presented was a function of the subject's response (see 14 for a more detailed discussion of the up-and-down method). Stimulus orientation was randomly selected, and an independent up-and-down series was maintained for each of the eight orientations.

Both subjects were tested at a target velocity of 110° /sec. first. An experimental session continued until the subject decided that he could no longer perform properly. When testing continued, it began where it had left off in the up-and-down series.

RESULTS

ANALYSIS OF THRESHOLD DATA

In order to minimize the effects of practice and to adhere to the precepts of the up-and-down method, the first series of descending or ascending judgements plus the next 8 responses were disregarded from the data analysis. Thus, the final 48 responses for each of 8 orientations were selected for analysis. Each of these sequences of 48 responses was divided into 12 blocks of 4 and a mean for each block computed. This yielded 12 threshold estimations for each orientation. Table 1 presents the mean and standard deviation associated with thresholds for each subject as a function of target angular velocity and orientation.

An analysis of variance with respect to the main effects of Angular Velocity, Subjects, and Orientation revealed significant main effects of Angular Velocity ($F(1,22) = 374.07$, $p < 0.001$), and Orientation ($F(7,154) = 58.3$, $p < 0.001$), plus a significant Subjects x Orientation interaction ($F(7,154) = 8.32$, $p < 0.001$). Figures 1 and 2 illustrate the pooled mean acuity thresholds and their standard deviations in minutes of visual arc for each orientation at angular velocities of 110° /sec. and 20° /sec., respectively. As can be observed from these Figures

Table I

Mean Threshold and Standard Deviation in Minutes of
Visual Arc For Each Subject as a Function of
Angular Velocity and Orientation

Orientation	Velocity	<u>DW</u>		<u>TM</u>	
		Threshold	S.D.	Threshold	S.D.
0°	20°/sec.	2.04	.327	1.81	.394
45°	20°/sec.	1.81	.375	1.89	.223
90°	20°/sec.	1.48	.349	1.16	.298
135°	20°/sec.	2.24	.529	1.71	.414
180°	20°/sec.	2.06	.292	1.72	.403
225°	20°/sec.	1.83	.331	1.72	.448
270°	20°/sec.	2.39	.681	1.23	.289
315°	20°/sec.	1.93	.215	2.00	.647

0°	110°/sec.	3.82	.648	4.89	1.187
45°	110°/sec.	4.22	.656	3.71	.791
90°	110°/sec.	4.11	1.235	2.73	.677
135°	110°/sec.	3.56	.732	3.32	1.022
180°	110°/sec.	3.43	.372	4.69	1.061
225°	110°/sec.	4.06	.768	3.98	.608
270°	110°/sec.	4.20	1.013	3.43	.715
315°	110°/sec.	3.50	.490	4.01	.517

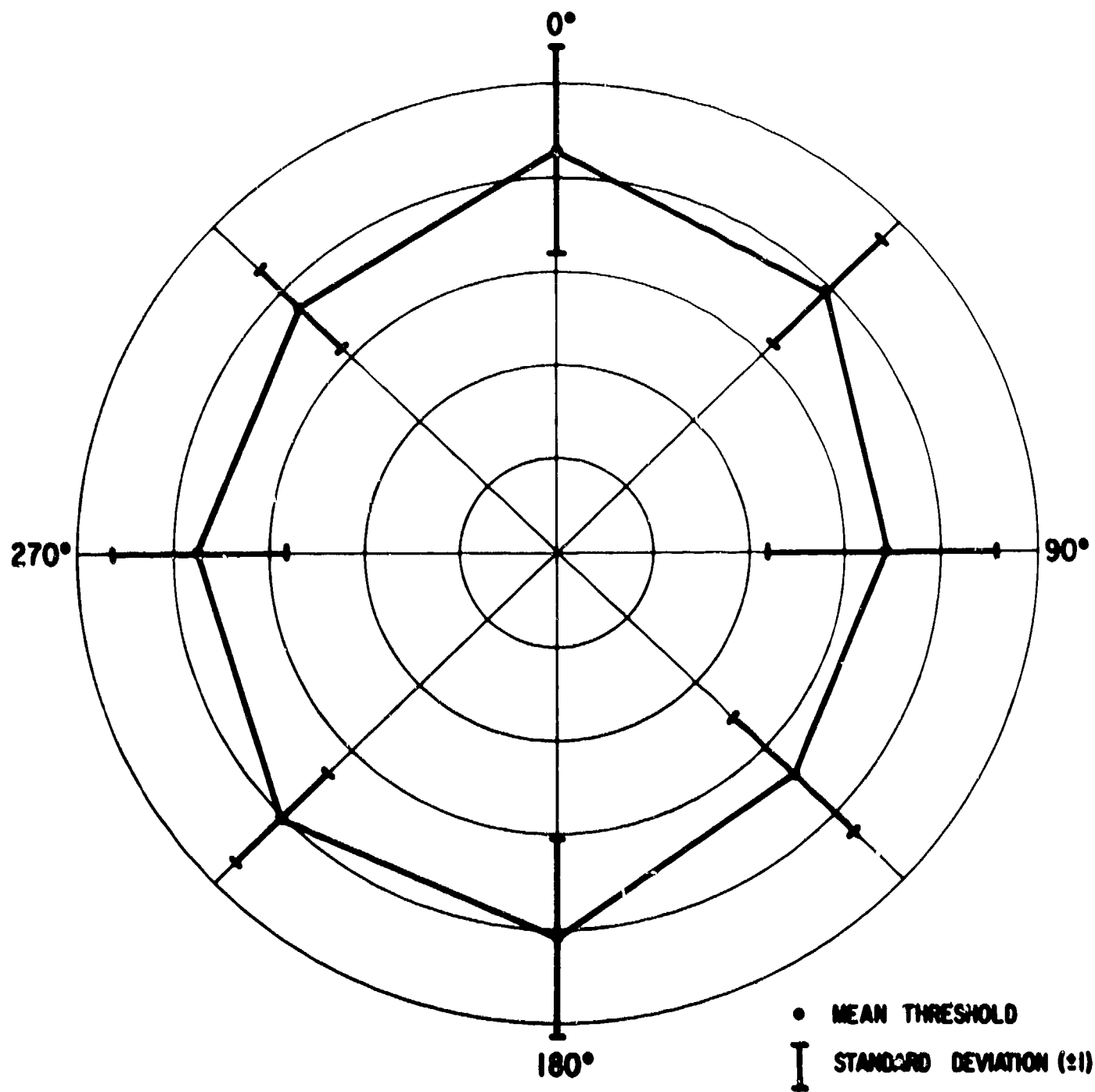


Figure 1: Mean threshold and standard deviation for each orientation at an angular velocity of $110^\circ/\text{sec}$. Each concentric ring equals one minute of visual arc.

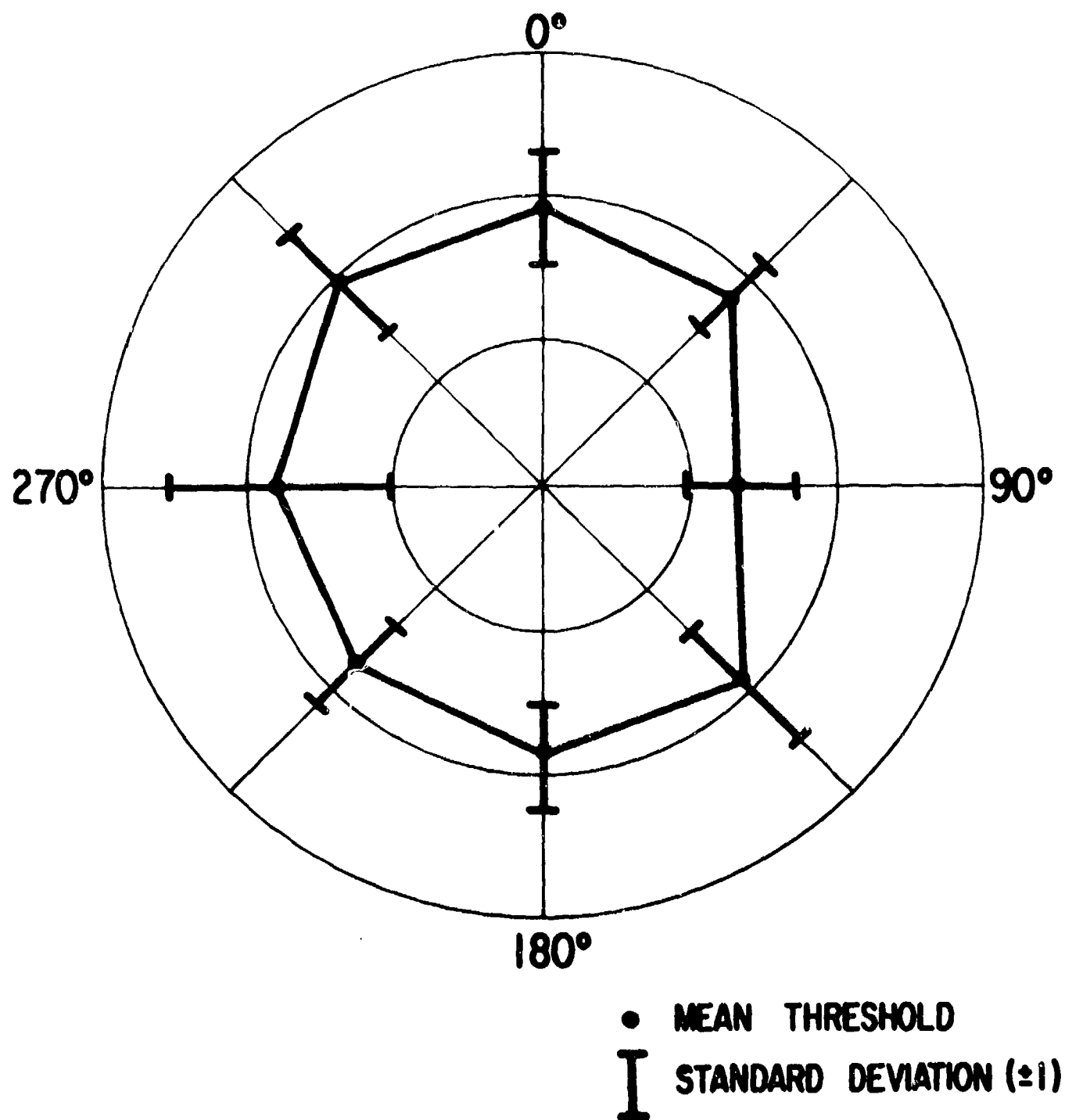


Figure 2: Mean threshold and standard deviation for each orientation at an angular velocity of $20^\circ/\text{sec}$. Each concentric ring equals one minute of visual arc.

and Table I, both subjects consistently had higher thresholds at an angular velocity of $110^{\circ}/\text{sec.}$ and, in general, the higher the mean the greater the variability about that mean. Due to the observed differences in variability about the means, an F-Max test for homogeneity of variances was conducted, which yielded a nonsignificant F-quotient.

ANALYSIS OF RESPONSE-BIAS DATA

The probability of occurrence of a particular stimulus orientation on any trial was 0.125. In order to ascertain each subject's response bias, confusion matrices were constructed representing the proportion of incorrect responses made to each orientation for each subject. Table II presents these values. A matrix was not constructed for subject DW at $110^{\circ}/\text{sec.}$ since this aspect of the data was not recorded for this subject.

Analysis of variance on each of the confusion matrices yielded significant differences across orientations for subject DW at $20^{\circ}/\text{sec.}$ ($F(7,48) = 5.83$, $p < 0.001$) and for subject TM at $20^{\circ}/\text{sec.}$ ($F(7,48) = 2.98$, $p < 0.025$), and $110^{\circ}/\text{sec.}$ ($F(7,48) = 5.13$, $p < 0.001$). Since each of the confusion matrices were analyzed separately, information on the interactions between the factors of angular velocity, orientation, and subjects are not discernible. The Subjects x Orientation interaction for the threshold data would suggest that perhaps the subjects differed in their biases to the various orientations.

DISCUSSION

The results of the present study indicate that visual acuity decreases as the angular velocity of the stimulus increases. This finding is in agreement with previous research by Miller and Ludvigh (11), and Brown (4). The data further demonstrated an orientation effect, but it was not an oblique effect. That is, thresholds were not consistently higher for oblique orientations.

The results of the confusion matrices analysis revealed that a significantly higher proportion of incorrect responses were made to some orientations than others, indicating response bias. In order to determine the relationship between the response-bias scores and the threshold scores, a Spearman Rank-Order correlation was computed after collapsing the data across subjects and angular velocity. A significant correlation coefficient of -0.928 ($p < 0.001$) was obtained. This finding suggests that response bias contributes to the magnitude of the psychophysically measured acuity thresholds. That is, the more likely a subject is to respond to a particular orientation, the lower the corresponding threshold. Weitzman, Smith, and Karasik (13) have suggested that psychological decision processes in response strategies are as important in orientation effects as neurological factors. The results from this experiment would support that contention.

Table II
Proportion of Incorrect Responses Made to Each
Orientation. The Response-Bias Data

Orientation	20°/sec.		110°/sec.
	DW	TM	TM
0°	1.45	13.16	4.44
45°	9.49	11.05	16.67
90°	27.74	22.63	25.00
135°	10.95	13.16	17.22
180°	8.03	5.79	10.00
225°	10.22	4.21	11.11
270°	20.44	12.63	7.78
315°	11.68	17.37	7.78

EXPERIMENT II

Experiment II was conducted to provide a control study for Experiment I, by determining whether the oblique effect would be obtained using the present apparatus under static conditions, and to ascertain if the oblique effect could be explained in terms of response bias.

METHOD

The subjects, the stimuli, and the apparatus were the same as in Experiment I, with the following exceptions: A flat black Uniblitz electronic shutter (Model 262X2HOX5) was mounted to the subject's chin-and-headrest assembly such that the mirror was obscured from the subject's view when the shutter was closed. Activation of a pushbutton switch by the subject's right hand opened the shutter for a 0.4-sec. duration exposing the stimulus image at the midpoint of the aperture. The mirror remained stationary throughout the experiment.

RESULTS

ANALYSIS OF THRESHOLD DATA

As in Experiment I, all responses up to and including the first reversal in the up-and-down series plus the next 6 responses were disregarded from the data analysis. The mean and standard deviation associated with the thresholds for each orientation, collapsed across subjects, are illustrated in Figure 3. Similarly, Table III presents the mean threshold and standard deviation across orientations for each subject.

A two-factor mixed analysis of variance with Orientation as the repeated measures variable was performed. The results of the analysis of variance yielded a significant main effect of Orientation ($F(7,154) = 17.22, p < 0.001$), and a significant Orientation x Subject interaction ($F(7,154) = 21.37, p < 0.001$).

ANALYSIS OF RESPONSE-BIAS DATA

Confusion matrices were formed and proportions were calculated as in Experiment I. Table IV presents the proportion of incorrect responses made to each of the eight orientation categories for each subject.

An analysis of variance with respect to the main effects of Orientation and Subjects, revealed a significant Orientation effect ($F(7,91) = 2.50, p < 0.025$) and a significant Orientation x Subject interaction ($F(7,91) = 2.41, p < 0.05$).

DISCUSSION

The results of the present experiment demonstrate an orientation effect. However, contrary to other studies on meridional variations in acuity, oblique thresholds were not consistently higher than cardinal. The explanation for this particular outcome can perhaps be explained in terms of the test stimulus. Typically, gratings and line stimuli are utilized in experiments on orientation effects. A Landolt C in a particular orientation may not be comparable to a line or grating of the same orientation. For example, a line oriented at 45° is also oriented at 225° . An examination of the literature reveals that the orientations most commonly used in studies of the oblique effect are 315° , 0° , 45° , 90° , and 135° . When these meridional axes are examined in the present study, an oblique effect is observed.

A nonsignificant Spearman Rank-Order correlation coefficient of -0.333 was found between the response-bias scores and the acuity-threshold scores across orientation. However, since the correlation was in the expected direction, it lends support to the findings of Experiment I.

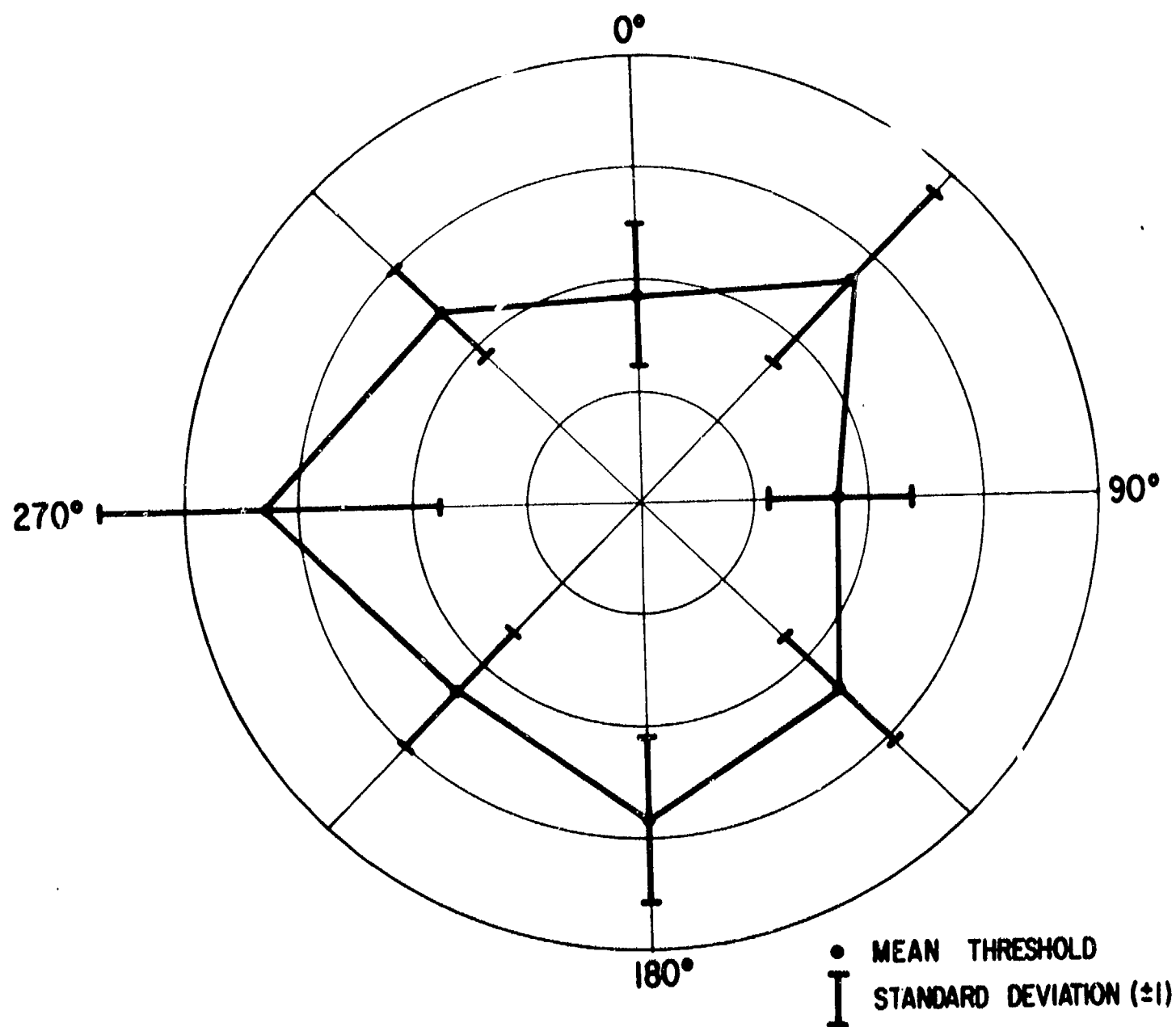


Figure 3: Mean threshold and standard deviation for each orientation at an angular velocity of 0°/sec. Each concentric ring equals one minute of visual arc.

Table III
Mean Threshold and Standard Deviation in Minutes of
Visual Arc for Each Subject as a Function
of Orientation at 0°/sec.

Orientation	DW		TM	
	Threshold	S.D.	Threshold	S.D.
0°	1.78	.343	1.98	.835
45°	3.20	1.147	2.25	.805
90°	1.35	.427	2.07	.580
135°	2.74	.698	2.08	.443
180°	2.41	.781	3.19	.486
225°	1.95	.440	2.84	.708
270°	4.48	.894	2.08	.479
315°	2.15	.441	2.68	.578

Table IV
Proportion of Incorrect Responses Made to Each
Orientation at an Angular Velocity of 0°/sec.
The Response-Bias Data

Orientation	DW	TM
0°	15.59	13.73
45°	13.98	9.35
90°	17.74	15.93
135°	6.98	16.48
180°	5.38	7.69
225°	9.68	9.35
270°	11.83	19.78
315°	18.82	7.69

GENERAL DISCUSSION

As can be seen from Figures 2 and 3, the mean acuity thresholds for a stationary target were higher for each subject than for a target moving at a velocity of $20^\circ/\text{sec}$. Moderate differences between these two conditions would not be surprising, since Experiment II introduced a shutter between the subject's eye and the mirror. The opening of the shutter diaphragm could have influenced the measured acuity thresholds by any of the following: (i) initiating an eye-blink, (ii) initiating an accommodative change from near to far, or, (iii) initiating a change in light adaptation by altering the amount of light reaching the retina.

In summary, a significant orientation effect was found for both dynamically and statically presented targets, but it was not an oblique effect. The data further demonstrated that erroneous responses were not equally distributed over orientations, indicating response bias. A significant negative rank-order correlation was found between the subjects' response-bias scores and their threshold scores across orientation for moving targets, but not for statically presented targets. However, the data are suggestive that tests of acuity that depend upon responses to stimulus orientations may provide spurious measures as a function of response bias. If a subject's response bias could be partialled out from the acuity threshold score, a more accurate estimate of the subject's threshold could be given. This procedure would further afford a means to assess the relative contributions of judgemental and neural components in orientation effects.

CONCLUSIONS

1. Acuity was found to decrease as the angular velocity of the stimulus increased.
2. An orientation effect was found for both dynamically and statically presented targets, but it was not an oblique effect.
3. The subjects' response biases were found to vary across orientations for both moving and static targets.
4. A significant negative rank-order correlation was found between the subjects' response-bias scores and their threshold scores across orientations for moving, but not for statically presented targets. This suggests that response bias contributes to the error in the measurement of psychophysically derived acuity thresholds.
5. It was pointed out that the Landolt C is unlike typical stimuli used in tests of orientation effects, and that perhaps it may not be directly comparable to line stimuli and gratings.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NAMRL -- 1241 ✓	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Effects of Stimulus Orientation and Response Bias Upon Dynamic Visual Acuity		5. TYPE OF REPORT & PERIOD COVERED Interim
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Lawrence H. Frank		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Aerospace Medical Research Laboratory ✓ Naval Air Station Pensacola, Florida 32508		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS MF51.524.004-2011 W43-13 8881
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Medical Research and Development Command National Naval Medical Center Bethesda, Maryland 20034		12. REPORT DATE 19 August 1977
		13. NUMBER OF PAGES Fourteen (14)
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Stimulus Orientation Response Bias Dynamic Visual Acuity Oblique Effect		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) <p>In experiments on dynamic visual acuity, test stimuli are characteristically presented in various orientations to the subject as they are moved across his visual field. However, current literature on static visual acuity indicates that acuity thresholds vary as a function of stimulus orientation. Static acuity thresholds are reported to be lower for the vertical and horizontal orientations, whereas, higher thresholds are found for oblique orientations. This has been referred to the "oblique effect."</p> <p>It is not known whether the same phenomenon operates in dynamic visual acuity. Hence, it is of interest to determine whether such an effect occurs under moving target conditions. The present studies utilized the up-and-down method to determine acuity thresholds for eight orientations (4 cardinal and 4 oblique) of Landolt Cs over three angular velocities. Response-bias scores were computed for each subject and compared to the threshold data.</p>		

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